ULTRASONIC AND ELECTROPLATING APPROACH FOR WASHCOAT OF γ-ALUMINA AND NICKEL OXIDE (NiO) CATALYST ON FeCrAl SUBSTRATE FOR CATALYTIC CONVERTER

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DEDICATION

This thesis is dedicated to my father Mr. Jalis, my mother Ms. Nasi'ah and my sister Ms. Dwi Lusiana that has given their love, enthusiasm and really gave me an energy as well as encouragement when I need it.

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ABSTRACT

One of the technological advances was concentrated on the removal of pollutants from exhaust system by Three-Way Catalytic Converter (CATCO). Metallic material potential to replace the ceramic material, therefore FeCrAl substrate used as metallic material and γ-Al_2O_3 as washcoat material and NiO catalyst. This study propose ultrasonic and electroplating approach as coating technique which not fully explored. Several problems in developing CATCO such as washcoat layer is spalling since the loose adhesion and unstable oxide growth in long term oxidation. Therefore, the main objective of this study are to embed γ-Al_2O_3 into substrate, to improve thermal stability as well as to improve conversion efficiency of exhaust gas emission. The methods performed in this study by ultrasonic bath (UB) using ethanol solution with frequency of 35 kHz and holding time of 1, 1.5, 2, 2.5 and 3 h respectively, electroplating technique (EL), ultrasonic bath during electroplating (UBdEL) and combination of UB and EL which is called by UB+EL technique that conducted by sulphamate type solution, current density of 1.28 A and holding time of 15, 30, 45, 60 and 75 minutes. The results shows that γ-Al_2O_3 has been embedded into FeCrAl substrate which develop several compounds such as FeCrAl, FeO, γ-Al_2O_3, $FeCr_2O_3$, NiO, $NiAlO_4$, $NiCr_2O_4$ and NaO_2. Appropriate coating thickness of coated FeCrAl was observed in UB+EL samples of 9.1 to 12 µm. The thermal analysis shows the smallest mass change located at UB+EL 30 minutes sample for 2.85 mg. Therefore, UB+EL 30 min was selected to be a method for FeCrAl CATCO development. Coated FeCrAl CATCO more effective to reduce fuel consumption up to 1.693 L/h and increase torque of 95 Nm, reduce NO_x up to 91.66% and HC emission up to 81.4% as well as reduce exhaust gas temperature up to 20.58% as compared to conventional ceramic and metallic CATCO. Therefore, an appropriate techniques and parameter is UB+EL 30 min used for coating FeCrAl CATCO potential to improve physical properties and reduce emission.

ABSTRAK

Salah satu kemajuan teknologi adalah tertumpu pada penyingkiran bahan pencemar dalam sistem ekzos dengan *Three-Way Catalytic Converter (CATCO)*. Bahan logam berpotensi untuk menggantikan bahan seramik, oleh itu FeCrAl substrat digunakan sebagai bahan logam dan γ-Al_2O_3 dan NiO. Kajian ini mencadangkan kaedah ultrasonik dan penyaduran sebagai teknik salutan yang belum diterokai sepenuhnya. Terdapat beberapa masalah dalam membangunkan *CATCO* seperti lapisan salutan yang mengupas kerana lekatan longgar dan pertumbuhan oksida yang tidak stabil. Oleh itu, objektif utama kajian ini adalah untuk menyalutkan γ-Al_2O_3 ke dalam substrat, untuk meningkatkan kawalan pengoksidaan dan kestabilan haba serta meningkatkan kecekapan penukaran pencemaran oleh *CATCO*. Kaedah yang dilakukan dalam kajian ini dengan menggunakan teknik UB menggunakan etanol dengan frekuensi 35 kHz dan pelbagai masa iaitu 1, 1.5, 2, 2.5 dan 3 h, teknik EL, UBdEL, UB+EL yang dijalankan menggunakan larutan jenis sulphamate, ketumpatan arus 1.28 A dan pelbagai masa 15, 30, 45, 60 dan 75 minit. Keputusan menunjukkan bahawa γ-Al_2O_3 telah dimasukkan ke dalam substrat FeCrAl yang menghasilkan beberapa sebatian seperti FeCrAl, FeO, γ-Al_2O_3, $FeCr_2O_3$, NiO, $NiAlO_4$, $NiCr_2O_4$ and NaO_2. Ketebalan salutan yang bersesuaian ditunjukkan oleh sampel UB+EL dari 9.1 hingga 12 μm. Analisis termal menunjukkan perubahan massa terkecil di UB+EL 30 minit sampel iaitu 2.85 mg. Oleh itu, UB+EL 30 minit dipilih untuk menjadi kaedah untuk fabrikasi FeCrAl *CATCO*. FeCrAl *CATCO* lebih berkesan untuk mengurangkan penggunaan bahan api sehingga 1.693 L/h dan meningkatkan tork sehingga 95 Nm, mengurangkan NO_x hingga 91.66% dan pelepasan HC sehingga 81.4% serta mengurangkan suhu gas ekzos sehingga 20.58% berbanding dengan *CATCO* seramik dan logam konvensional. Oleh itu, teknik dan parameter yang sesuai ialah UB+EL 30 minit yang digunakan untuk lapisan FeCrAl *CATCO* untuk meningkatkan sifat fizikal dan mengurangkan pelepasan gas pada sistem ekzos.

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LIST OF SYMBOLS AND ABBREVIATION

γ-Al_2O_3	-	Gamma Alumina
µm	-	Micrometer
A/F	-	Air/Fuel
AFM	-	Atomic Force Microscopy
A/dm^2	-	Ampere/Decimeter square
ASTM	-	American Standard for Testing and Materials
Al_2O_3	-	Alumina
BMEP	-	Break Mean Effective Pressure
BSE	-	Back Scattered Mode
BSFC	-	Brake Specific Fuel Consumption
CO	-	Carbon Monoxide
CPS	-	Count Per Second
CTE	-	Coefficient of Thermal Expansion
$C_{12}H_{25}SO_4Na$	-	Sodium lauryal sulphate
$C_{12}H_{25}OSO_3.Na$	-	Sodium dodecyl sulfate
CATCO	-	Catalytic converter
DoE	-	Department of Environment
EDS	-	Energy Dispersive Spectroscopy
EBSD	-	Electron Backscattered Diffraction
FeCrAl	-	Ferum Chromium Aluminium
FeCr	-	Iron Chromium
g/l	-	Gram/liter

HC	-	Hydro-Carbon
H_2	-	Hydrogen
HV	-	Vickers Micro-Hardness
HCl	-	Hydrochloric Acid
HIWI	-	Hot Incipient Wetness Impregnation
H_2SO_4	-	Sulphuric acid
HP	-	Horse Power
H_2BO_3	-	Boric acid
kHz	-	Kilo Hertz
kPa	-	Kilo Pascal
k_p	-	Parabolic Rate Constant
LTC	-	Low Temperature Combustion
mm	-	Millimeter
MPa	-	Mega Pascal
MTBE	-	Methyl-Tertiary Butyl Ether
NO_x	-	Nitrogen Oxides
NiO	-	Nickel Oxide
$Ni(SO_3NH_2)_2\ 4H_2O$	-	Nickel sulphamate
$NiCl\ 6H_2O$	-	Nickel sulphamate
$NiSO_4.6H_2O$	-	Nickel (II) sulphate 6-hydrate
$NiCl_2 \cdot 6H_2O$	-	Nickel (ii) chloride
NaOH	-	Sodium Hydroxide

O_3	-	Ozone
OSC	-	Oxygen Storage Capacity
PCA	-	Process Control Agent
PM	-	Pariculate matter
Pt	-	Platinum
Pd	-	Lead
RON	-	Research Octane Number
rpm	-	Radian per Minute
SiO_2	-	Silicon Oxide
SiO_2-Al_2O_3	-	Silicon Oxide- Alumina
SCS	-	Solution Combustion Synthesis
S/cm	-	Siemens per centimeter
SEM	-	Scanning Electron Microscope
SEI	-	Secondary-Electron Image
SCS	-	Solution Combustion Synthesis
TWC	-	Three Way Catalyst
TiO_2	-	Titanium Oxide
THC	-	Total Hydro-Carbon
W	-	Watt
XRD	-	X-Ray Diffraction
Y	-	Yttrium

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